

# Management Model for Rungan Watershed, Central Kalimantan, Indonesia: A Comprehensive Approach to Achieving Conservation and Community Development Goals

Endy<sup>1</sup>, I Nyoman Sudyana<sup>1</sup>, Herwin Sutrisno<sup>1</sup>, and Raden Mas Sukarna<sup>2\*</sup>

<sup>1</sup>Doctoral Program in Environmental Science, University of Palangka Raya, Campus UPR Tunjung Nyaho, Palangka Raya, Central Kalimantan, Indonesia

<sup>2</sup>Department of Forestry, Faculty of Agriculture, University of Palangka Raya, Campus UPR Tunjung Nyaho, Palangka Raya, Central Kalimantan, Indonesia

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### \* Corresponding author:

E-mail: sukarna@for.upr.ac.id

## ABSTRACT

The Rungan Watershed is facing an alarming rate of environmental degradation yet continuing to support the livelihoods of local communities. Therefore, this study is essential for addressing these issues and formulating adaptive management model. This research aims to assess environmental conditions and social economic aspects to formulate management model that is expected to serve as a framework for sustainable development in Palangka Raya City. By applying both qualitative and quantitative approaches, the study collects ecological, economic, and socio-cultural data to inform the development of management strategies. Land cover, land use, and vegetation density are assessed using remote sensing imagery and land cover maps. The analysis of forest vegetation density classes is conducted through the Normalized Difference Vegetation Index (NDVI), utilizing data from Landsat imagery. Socio-cultural information is gathered through interviews and observations. The study identifies various land cover condition, information on social economic condition that serve as a basis for developing a zoning based management model that categorizes the Rungan Watershed into conservation, buffer, and general utilization zones. This model accommodates the diverse interests of multiple stakeholders within a sustainable development framework. The study concludes that the zonation management of the sub-basin must align with the biophysical ecological conditions of the area, address existing challenges, and promote community welfare.

## HIGHLIGHTS

This study employs a comprehensive approach to designing a management model for the Rungan Watershed, given the complexity of the challenges it faces. Ecological conditions, socio-economic factors, and cultural aspects are integrated to create a zoning management framework that accommodates the diverse interests of multiple stakeholders in support of sustainable development goals. The principles and approaches used in this research are applicable to land management worldwide under similar conditions.

## 1. INTRODUCTION

The future development direction of Central Kalimantan will focus on two key goals mandated by the central government: serving as a national food production centre and a world conservation center (Government of Central Kalimantan, 2024). To achieve this development vision, particularly the Smart Environment Vision, it is essential to maintain a diverse ecosystem, which plays a crucial role in enhancing the welfare of the city and the livelihoods

of its population. This approach aligns with efforts to meet sustainable development targets (Addai et al., 2023; Birkmann et al., 2022; Masot and Gascon, 2021).

The principle of sustainable development should also be applied in managing an area, particularly watersheds, to maintain a balance between biodiversity preservation and the optimal use of environmental services by prioritizing the active role of the community (Mengistu and Assefa, 2021; Narendra et al., 2021;

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Okiria et al., 2021; Shunglu et al., 2022). Essential ecosystem values, such as biodiversity, corridors for animal movement, and support for community livelihoods, must receive significant attention in development management design (Meena et al., 2022; Wang et al., 2023). This approach ensures that the environment can continue to support sustainable development (Ojelel et al., 2024). Watersheds in Central Kalimantan are vital to the region's ecosystem, as most of its ecosystems are shaped and influenced by rivers, therefore, formulating an adaptive management system of watershed is paramount.

Adaptive watershed management must consider the characteristics and uniqueness of each watershed to avoid damage and prevent broader environmental degradation. According to the latest watershed concepts formulated by experts, watersheds are understood not only as landscapes with topographic boundaries and hydrological unity but also as ecosystem units (Arnillas et al., 2021; Zhao and Huang, 2022). Watershed areas do not always align with specific administrative boundaries, often resulting in overlaps and conflicts of interest among various sectors. Therefore, integrated watershed management is necessary to achieve optimal conditions for the natural resources within these areas, ensuring that these resources can provide sustainable benefits for human welfare (Mosaffaie et al., 2021; Srivastav et al., 2021; Waskitho et al., 2021).

Apart from its significant role in supporting the environment and sustainable development, the Rungan watershed faces several environmental challenges. Traditional gold mining by local communities along the watershed leads to issues such as river pollution, damage to riparian areas, and disruption of fish habitats and life cycles. Additionally, deforestation and forest exploitation in the region contribute to the disturbance and fragmentation of wildlife habitats. Furthermore, its proximity to the city of Palangka Raya has further subjected the Rungan watershed to land cover changes for residential and infrastructure development.

The research related to river mostly focuses on one specific topic, for example, water erosion (Hagras, 2023), water pollution (Basuki et al., 2024; Ismanto et al., 2023), water quality (Marselina et al., 2022) and flooding (Hagras, 2025). Discussions about water management or watershed management generally focus on improving economic aspects and crop productivity (Hairani and Noor, 2020; Mainardis et al., 2022; Islam et al., 2022). Thus, research on water

management using a comprehensive approach remains limited.

Research on watershed management in Indonesia has highlight the importance of implementing sustainable watershed management. Supangat et al. (2023) discuss the importance of creating productive (Easter et al., 1985) and healthy watersheds through coordination and synchronization of programs among various related parties. This idea is based on the understanding that one of the main causes of watershed degradation is the lack of coordination between institutions and the pressure of anthropogenic activities. Basuki et al. (2024) argue that it is important to increase the integration of watershed management into climate change mitigation and adaptation efforts in Indonesia. Hairani and Noor (2020) specifically reviewed water management on peatlands for the purpose of agricultural and plantation development. They recommend combining technology and research results in managing water on peatlands to maintain ecological integrity while increasing agricultural productivity. Alhakim et al. (2025) studied the hydrological behavior of the Raya watershed in West Kalimantan in response to watershed characteristics. Various studies have also found that the government has implemented various program initiatives such as policy frameworks, institutional structures, and community-based management initiatives. However, these programs are considered unable to overcome the various obstacles faced by watershed management (Basuki et al., 2024; Narendra et al., 2021). The implementation of watershed management in Indonesia faces several major obstacles, such as a lack of program synchronization among stakeholders, bureaucratic confusion, and a lack of stakeholder participation, especially from the community, in the planning process (Narendra et al., 2021).

In response to these gaps and research needs, this study purposes a comprehensive approach by assessing land cover characteristics, collecting economic and social information from stakeholders, to develop an integrative and sustainable watershed management framework that synergizes program from different stakeholders in the Rungan Watershed. Integrative management planning can help implement strategic actions that promote environmentally friendly conservation and development efforts. This study adopts a comprehensive approach to develop a watershed management model, which has still been limitedly utilized in previous studies. The goal of this research is to establish priorities for the Rungan Sub-

Watershed management program, serving as a guideline for sustainable development in Palangka Raya City.

## 2. METHODOLOGY

The research applies a mix methods approach using qualitative and quantitative methods derived from the constructivist and positivist paradigms (Creswell, 2021).

### 2.1 Research location

The research was focused on the Rungan River Watershed in Palangka Raya Central Kalimantan Province, Indonesia (Figure 1). The research was carried out for five months, from January to May 2025 which including preliminary observation activities, preparation of research frameworks and tools, data collection, analysis and reporting.

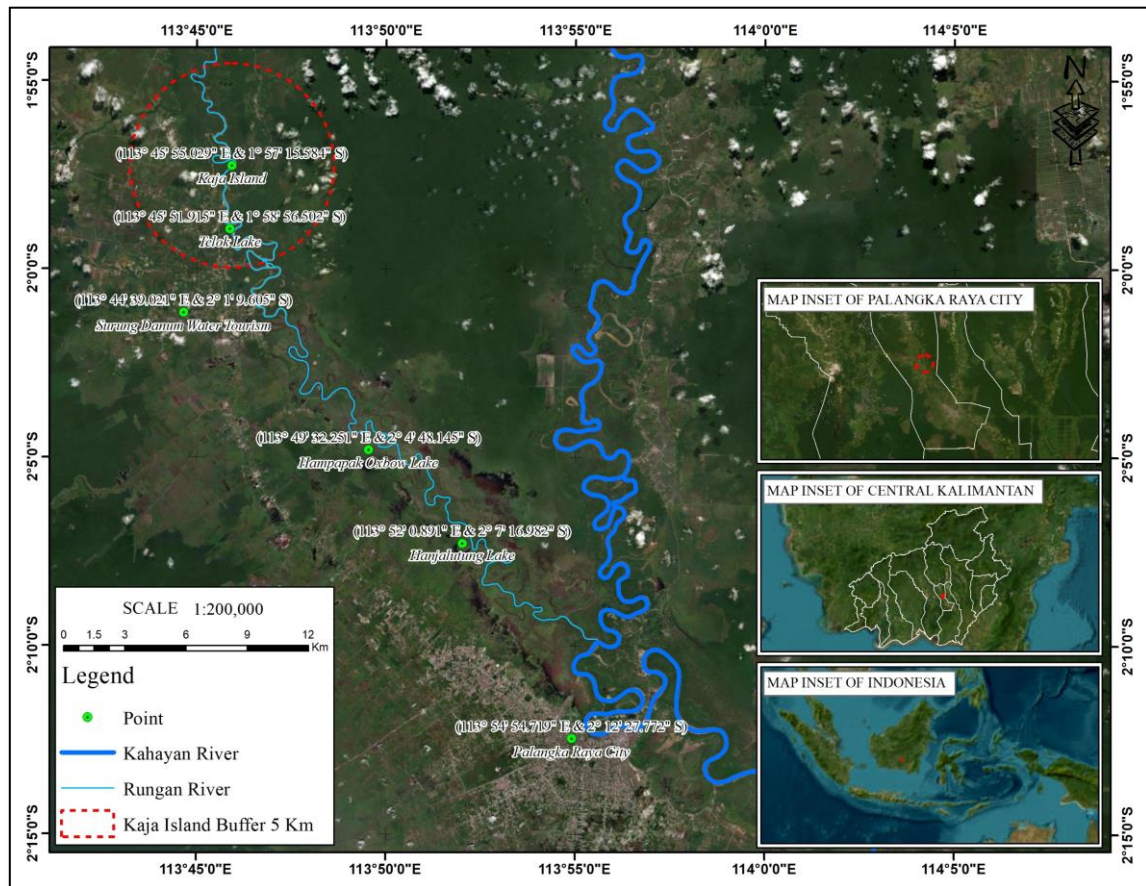


Figure 1. Map of the research location

### 2.2 Data analysis

#### 2.2.1 Data category

The data were categorized based on their source (Rahmadi, 2011).

1) Primary Data: These are data obtained directly from the original source at the research location. In this study, primary data includes information on the condition of the Rungan Sub Basin ecosystem, the socio-economic data of the community, and the challenges faced by both the community and the government in managing the area. Socio-economic data were collected using interviews and Focus Group Discussions (FGDs). Interviews

were conducted using open- ended questions with 20 local community members, 10 Government Institution employees, 4 NGOs representatives and 2 Private sector representatives. In addition, two FGDs was conducted with local communities and other stakeholders.

2) Secondary Data: these are is sourced from non-primary references. In this study, secondary data include literature, Landsat images of land cover, population data of protected species, and other supporting data accessed online.

The analysis of ecosystem conditions aims to determine the area's status, potential, and threats,

serving as a key basis for preparing the Ruang Sub-Watershed management model. Understanding the significant value of an area is essential for minimizing potential negative impacts. At this stage, the required data primarily consists of secondary sources, including RTRW base maps, RTRW thematic maps, land capability unit maps, and large scale spatial data. The socio-economic descriptive analysis of the study area seeks to compile and elaborate on various data, incorporating both secondary information from local governments and primary data from surveys, to identify potential opportunities and challenges across different sectors.

### 2.2.2 Bio-physical analysis

Bio-physical analysis was carried out through a spatial approach and field surveys using the following steps.

#### a) Vegetation density analysis

Vegetation density analysis was conducted by examining land cover/land use and vegetation density using remote sensing imagery and land cover maps. The analysis of forest vegetation density classes utilized Normalized Difference Vegetation Index (NDVI) data from Landsat 8 OLI path/row 118061, dated July 26, 2024.

$$NDVI = (NIR - Red) / (NIR + Red) \quad (1)$$

Where; NIR is the near-infrared reflectance and Red is the visible red light reflectance. This index helps to assess vegetation health by leveraging the fact that healthy vegetation absorbs a significant amount of red light and reflects a large amount of near-infrared light (Bannari et al., 1995; Kaufmann et al., 2003).

#### b) Physical land analysis

Physical land analysis in this study involved mapping peat depth classes and peat hydrological units using spatial data. This process employed a deductive approach to categorize the combined spatial data into distinct groups. The categories included peatland types, based on a combination of 20-cm contour-based peat elevation and peat depth data obtained from the Peat Ecosystem Function, as well as land cover categories that encompass various land cover types, permit areas, forest zones, and sub-peatland hydrological units.

#### c) Overlay and criteria combination

The overlay analysis approach was used to combine various spatial criteria to obtain appropriate zoning patterns. Commonly used tools included Intersect, Union, and Raster Calculator (for raster data).

The analysis process for vector data included:

1. Performing an Intersect between the 1-km buffer, HCV (High Conservation Value/NKT) layers, and land cover.
2. Adding the peat depth layer through the Intersect method or by converting the depth raster into polygons beforehand.

The classification system was conducted by assigning weighted values to each class within every criterion based on its importance for conservation or area management. The scoring table used was as follows Table 1.

**Table 1.** Criteria combination

| Criteria   | Class                | Score |
|------------|----------------------|-------|
| HCV (NKT)  | HCV 1                | 3     |
|            | HCV 2                | 2     |
|            | Non-HCV              | 1     |
| Peat       | Deep (>3 m)          | 3     |
|            | Medium (2-3 m)       | 2     |
|            | Shallow (<2 m)       | 1     |
| Land cover | Primary forest       | 3     |
|            | Shrub/Farmland       | 2     |
|            | Open land/Settlement | 1     |

After assigning values, the scores of each criterion were summed for every spatial unit resulting from the overlay. This total score was then used to classify the zoning. Based on the calculated total scores, the zoning classification was determined as follows Table 2.

**Table 2.** Zoning score

| Total score | Zoning                   |
|-------------|--------------------------|
| 7-9         | Core conservation zone   |
| 5-6         | Buffer zone              |
| 3-4         | General utilization zone |

This classification served as the basis for decision-making in managing areas according to their environmental function and sensitivity based on data as follows Table 3.

**Table 3.** Summary of source of data

| Data                                 | Source                                                                                                                                                                                                                                    |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Social economic                      | Interview, observation, Central Bureau of statistic                                                                                                                                                                                       |
| Land cover                           | Digital land cover data interpreted from LDCM (The Landsat Data Continuity Mission)/Landsat 8 OLI imagery. Directorate of Forest Resource Inventory and Monitoring, Directorate General of Forestry Planning and Environmental Management |
| Peat soil depth                      | Provincial Spatial Plan (RPPEG) Map of Central Kalimantan Province                                                                                                                                                                        |
| High conservation value biodiversity | High Conservation Value Biodiversity Map of Central Kalimantan Province                                                                                                                                                                   |
| Forest area                          | Digital data of Forest Areas and Marine Conservation Areas of Indonesia as of December 2023, Directorate of Forest Area Establishment and Utilization, Directorate General of Forestry Planning and Environmental Management              |

### 3. RESULTS AND DISCUSSION

#### 3.1 Landscape ecology

GIS analysis of vegetation density, peat soil depth, and land cover shows that the Rungan Sub-Watershed area spans 337,148 hectares, managed under various permits and designations. [Figure 2](#) illustrates that the predominant use of this area is oil palm plantations operated by private companies. Other management permits in the region include the Forest Cultivation Business License and Industrial Plantation Forest, covering areas of 64,835 hectares and 25,201 hectares, respectively. Additionally, permits granted to mining companies encompass approximately 25,928 hectares. The state forest area that remains free from company licensing totals 105,879 hectares.

The results of the land cover analysis indicate that deforestation has occurred to accommodate oil palm plantations and industrial timber plantations. Deforestation in river basins can affect the hydrological balance of rivers and trigger flooding ([Narendra et al., 2021](#); [Ramadhan et al., 2023](#)). Therefore, management of the Rungan Watershed should prioritize on conserving the remaining forest cover and rehabilitating degraded areas. Land rehabilitation models in watersheds should consider land function. Land rehabilitation models in conservation areas will apply different models and techniques compared to those in production forest areas ([Ruslan et al., 2018](#)).

There are 12 types of land use in the Rungan Sub-Watershed: rivers, non-residential buildings, residential buildings, lowland forests, peat swamp forests, plantation forests, gardens with mixed crops, natural open land, cultivated open land, oil palm plantations, inland swamps, and shrubs, as shown in [Figure 4](#). An analysis of the natural forest cover types—specifically lowland forests and peat swamp forests—reveals that the natural cover in this region is significantly influenced by river flows and their

hydrological cycles. The river area spans 940 hectares, while the inland swamp covers 188 hectares. [Figure 3](#) illustrates the distribution of peat depth, which is essential information for developing a zoning strategy.

Natural conditions and the factors affecting them are crucial considerations for area management strategies. Based on its function, the Rungan Sub-Watershed is divided into production forests, conversion production forests, other use areas, and sea waters. The largest proportion consists of production forests, comprising more than 50%, while conversion production forests and other use areas have nearly balanced proportions of 21.62% and 27.37%, respectively. The functions of the conversion and other areas suggest the potential for future changes in land use. This insight can inform the development of management strategies aimed at anticipating the loss of carrying capacity due to the conversion of forest land use.

#### 3.2 Demography and livelihood

Based on secondary data from the Statistics Agency and results from field observations, the Rungan Sub-Watershed area encompasses more than 50 villages and sub-districts across Gunung Mas Regency and Palangka Raya City. The demographic characteristics of the community generally reflect those of rural areas, with low population density, a predominantly productive age group, and relatively low levels of education. The total population is approximately 45,000, with an average population density of less than 30 inhabitants per square kilometer.

The majority of the community consists of indigenous Dayak people, particularly Dayak Ngaju, along with a smaller number of immigrants from the Javanese, Banjar, and Bugis ethnic groups. Social and cultural ties remain strong, especially in the management of natural resources.

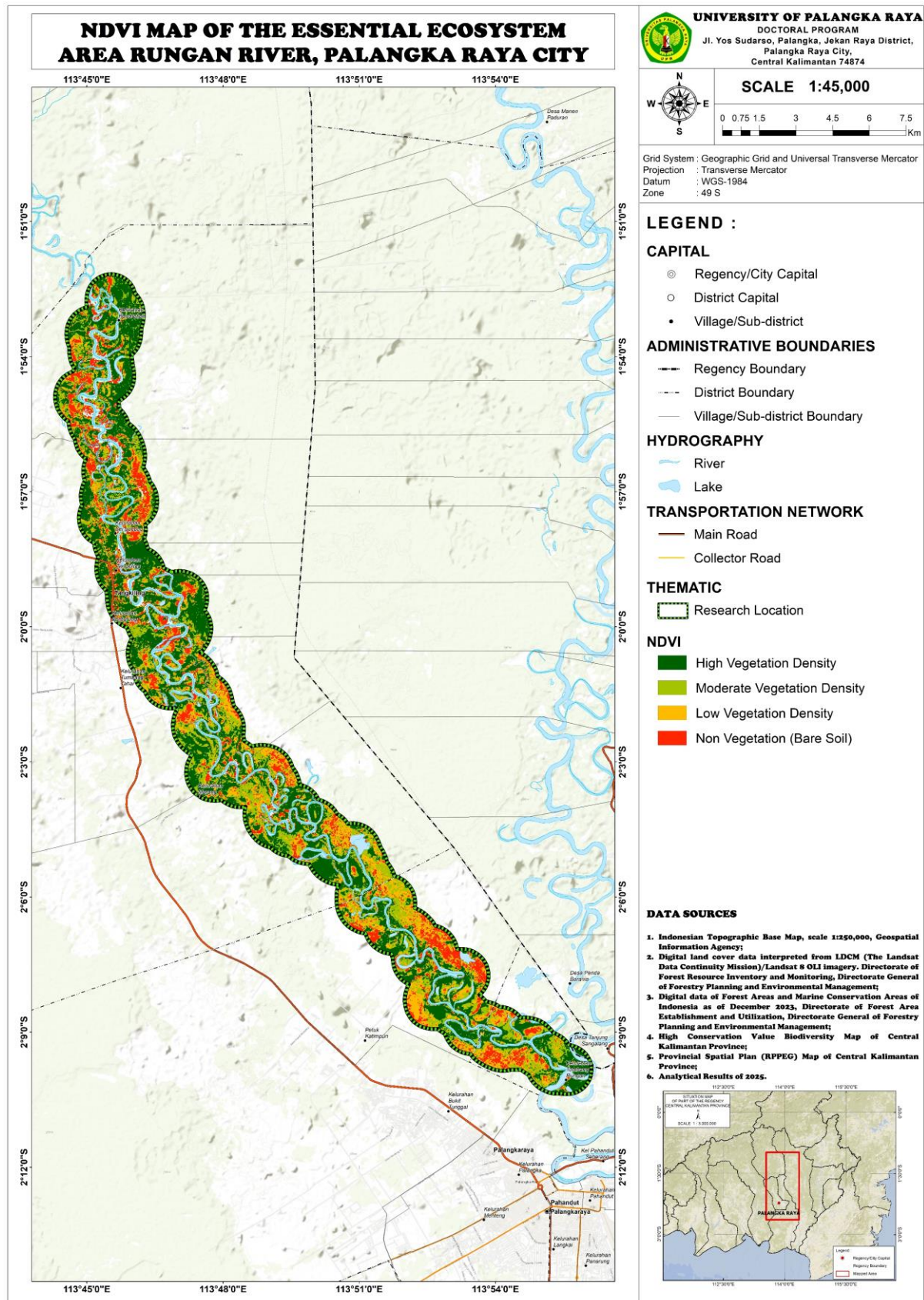


Figure 2. Map of vegetation density (NDVI Landsat 8) of Rungan Watershed

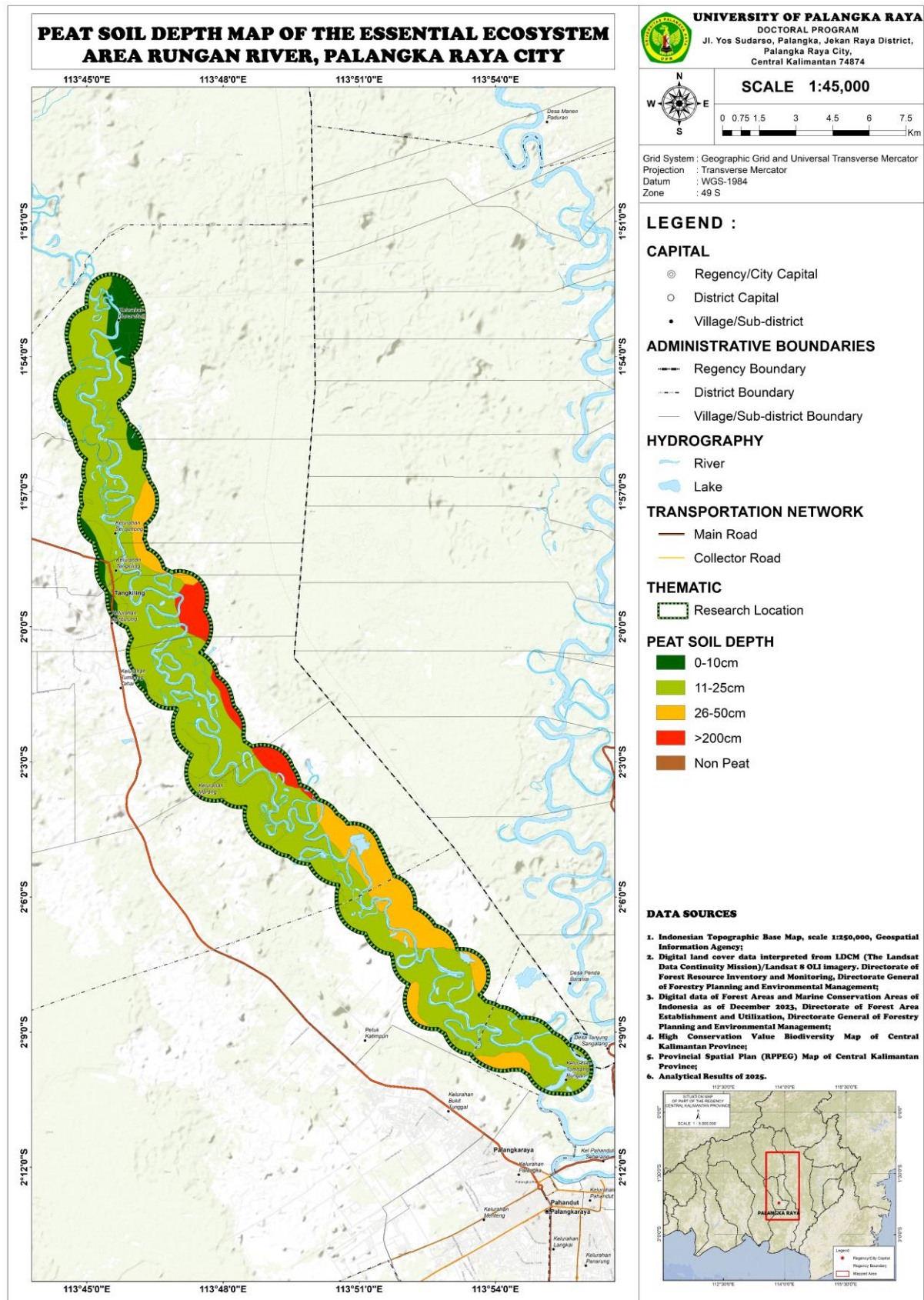


Figure 3. Map of peat soil depth of Rungan Watershed

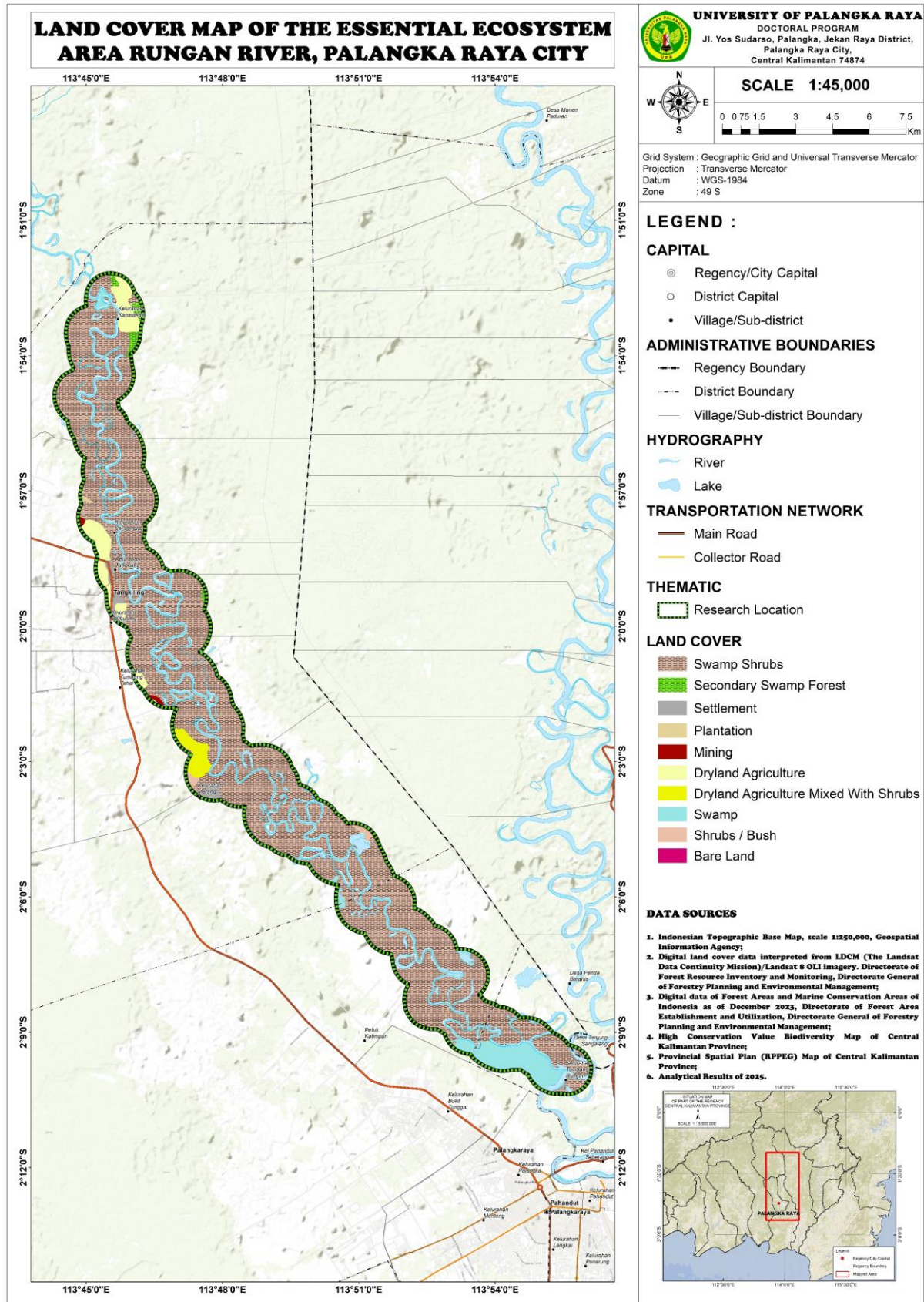


Figure 4. Map of land cover and land use of Rungan Watershed

The livelihoods of the people in the Rungan Sub-Watershed area heavily rely on natural resources

from rivers, forests, agricultural land, and gardens. Most community members engage in farming,

gardening, foraging for forest products, and fishing. Traditional methods of farming and gardening remain prevalent. Most of the community-owned plantations are in the form of agroforestry. These community agroforestry gardens provide a variety of products for subsistence and contribute to family income.

The results of secondary data analysis, community interviews and the expert opinions indicate several key socio-economic problems of the community, as follows:

- The community has a significant dependence on natural resources, including fisheries, plantations, and forest products. They lack access to modern technology to help them cope with extreme natural conditions, such as prolonged dry seasons, floods, and other hydrometeorological disasters. This vulnerability exposes them to damage from natural resource depletion and the impacts of climate change. A decline in the quality of these natural resources will profoundly affect their lives.

- The capacity of the community is still relatively low and has resulted in limited diversification of livelihoods. Furthermore, access to skill development opportunities is also limited, so most people do not have the skills to process natural or agricultural products into value-added products.

- The relatively low income of the community is one of the reasons for the limited processing of crops. In general, they still sell raw products.

- Another obstacle faced by the community is the limited marketing reach of the products they produce. Marketing is still local and conducted through collectors who come to the village. Limited access to financial institutions such as cooperatives and banks means that they lack sufficient capital to develop or intensify their livelihoods.

- There is a lack of integration between development and conservation programs. These two are still perceived as contradictory, with conservation efforts are often regarded as the limiting factor in people's livelihoods. However, if you look at the characteristics of people who have a depend on natural resources, conservation efforts can provide long-term security for livelihoods, whereas environmental degradation has negative impacts on people's livelihoods and well-being. Thus, there is a strong rationale for integrating natural resource conservation efforts with community welfare improvement. The development of a green economy that prioritizes the

principle of sustainability is one of the alternative solutions that can be offered.

The Rungan Sub-Watershed not only holds ecological richness, but also has high historical and cultural value. This area is part of the traditional residential area of the Dayak people, especially the Dayak Ngaju sub-tribe, who have lived and managed natural resources traditionally for hundreds of years. The traces of local civilization are imprinted in various aspects of life, ranging from belief systems, customs, land use, to the wisdom of ecosystem management.

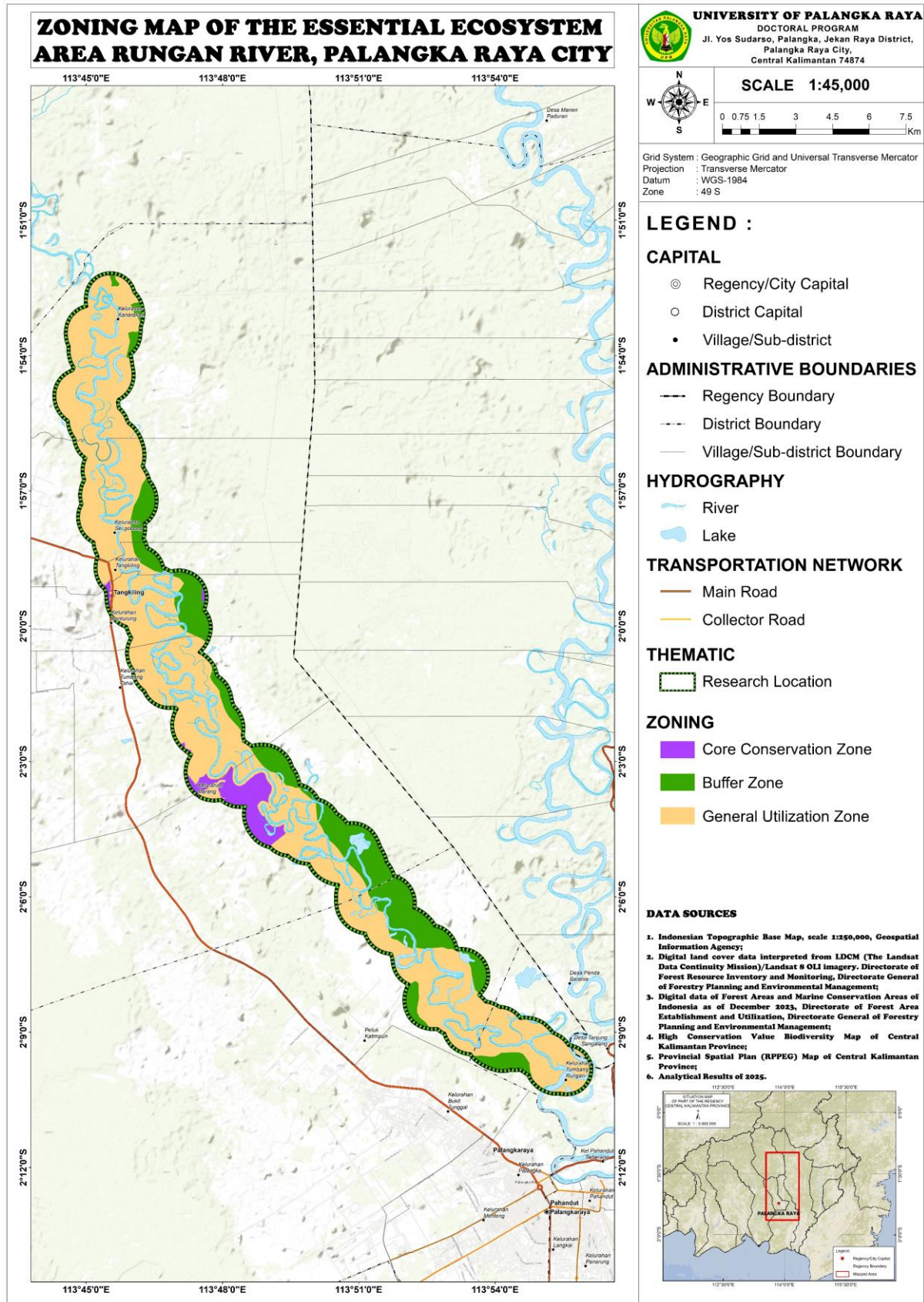
The utilization of forest resources by communities living around forests is one of the main focuses of forest empowerment programs. Forest and river environmental services are considered to have significant potential to contribute to improving community welfare (Wunder, 2001). However, this idea faces several limitations, such as limited access and rights over forest management, limited community capacity, and limited access to markets (Dewi et al., 2005).

### 3.3 Rungan Sub-Watershed management model and program

Based on biophysical analysis of the area, as well as socio-economic and cultural factors in the Sub-DAs Rungan region, this study formulates a management model.

The zoning arrangement model is part of spatial planning as stated in Indonesian Law No. 26/2007. Spatial planning is an activity that aims to regulate and supervise the use of space so that aligns with the Spatial Plan. These activities are carried out through zoning regulations, regulatory enforcement, incentives, permits and zoning control regulations (Lira, 2025).

The management zoning arrangement in the Rungan Sub-Watershed as shown in Figure 5, has a strategic role in addressing various problems while ensuring that diverse interests can be accommodated. Management zoning arrangements allow watershed ecological conservation and rehabilitation efforts to go hand in hand with community welfare improvement. The purpose of zoning is to establish the zoning of the Rungan River Essential Ecosystem Area in Palangka Raya City as the basis for spatial and thematic planning and management of the area. This zoning is intended to support efforts to conserve biodiversity, restore peat ecosystems, and manage natural resources sustainably. Zoning is carried out by considering the primary objectives of conservation, limited utilization, and risk-based management.



### 3.3.1. Core conservation zone

This area is designated as a core conservation zone due to its deep peat layers (greater than 3 meters), primary forest cover, and high biodiversity. These characteristics classify the zone as a high conservation priority. Land clearing and cultivation activities are prohibited in this zone to prevent damage to the ecological balance and the loss of biodiversity. Peatlands exceeding 3 meters in depth store significant carbon reserves, and converting them to agricultural land would release greenhouse gases such as carbon dioxide, methane, and nitrous oxide into the atmosphere.

Several types of programs can be implemented in core conservation zones, including efforts to protect and secure the area, inventory and monitor its status and biodiversity, conduct research and scientific development, and raise public awareness for its protection. Protection efforts can involve forming area monitoring units in collaboration with the community, thereby fostering active participation and awareness simultaneously. Additionally, it is important to install warning signs that prohibit logging, hunting, and land burning.

### 3.3.2. Buffer zone

The buffer zone serves as a protective area surrounding the core conservation zone, shielding it from potentially damaging human activities. This zone has a dual purpose: to preserve the environment and to support community welfare (He and Jiao, 2023). While economic activities are allowed within this zone, priority is given to those that are environmentally friendly and cause minimal impact.

The Rungan Sub-Watershed, particularly around Kaja Island and Sei Gohong, has significant potential for development into an ecotourism and educational hub. Field observations indicate that this area could serve as a center for orangutan reintroduction, fishing tourism, and river tourism. However, the ecotourism potential has not yet been managed optimally and has not contributed significantly to community income. Interviews with local residents reveal that community participation in ecotourism development is currently limited to providing boat rental services, which generate additional income ranging from Rp. 250,000 to Rp. 500,000.

Ecotourism can be leveraged as a strategic tool for area management to support and enhance various programs. It can serve as the “face” of diverse activities, increasing their marketability. By

promoting ecotourism, land rehabilitation efforts, community fishing activities, and enterprises based on medicinal plants and local cuisine can be made more attractive and economically valuable. Ecotourism acts as a link between environmental potential, society, and nature, fostering greater awareness and appreciation for the environment, biodiversity, and cultural heritage among the broader public.

Educational tourism, in particular, is a form of tourism that provides information and knowledge to visitors. Educational tours will make conservation efforts such as watershed rehabilitation, tree planting, fish conservation and orangutan conservation more engaging and informative. This is a new breakthrough for the development of tourism in this region. Educational tourism also serves as a mechanism to broaden community benefits, while simultaneously increasing public awareness of the importance of environmental and cultural conservation.

### 3.3.3. General utilization zone

This zone typically features land cover consisting of gardens, agricultural fields, and secondary forests. It hosts various community based economic activities, including gardening, farming, fishing, and gold mining. One potential development program for this area is the rehabilitation of degraded land through agroforestry systems. The primary focus of this rehabilitation is the land adjacent to the river, aimed at preventing erosion and protecting the Rungan sub-watershed ecosystem.

Rehabilitation efforts can involve planting endemic species such as Balawan (*Tristanopsis stellata* Ridl.), Resak (*Vatica rassak*), and Kempas (*Koompassia malaccensis*) (Setiarno and Wittu, 2018), alongside economically valuable plants species such as rubber (*Hevea brasiliensis*), petai (*Parkia speciosa*), and durian (*Durio zibethinus*).

Another program aims to encourage the development of sustainable livelihoods (Natarajan et al., 2022; He and Jiao, 2023) including the use of non-timber forest products, sustainable fisheries, and ecotourism. Developing alternative livelihoods is essential for gradually shifting communities away from environmentally harmful practices, such as illegal gold mining in rivers and illegal logging.

## 4. CONCLUSION

This study concludes that the sub-watershed management must align with the bio-physical and ecological conditions of the area to address existing challenges and enhance community welfare. This can

be achieved by implementing zoning- based management system, in which the Rungan Sub-Watershed is divided into three zones: the core conservation zone, the buffer zone, and the general utilization zone. This zoning approach protects areas of high ecological value while allowing development to proceed, and encourages coordination and collaboration among stakeholders.

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## AUTHOR CONTRIBUTIONS

Conceptualization, Writing-Original Draft Preparation; Writing-Review and Editing Endy, Randen Mas Sukarna; Writing, Formal Analysis, Endy, Herwin Sutrisno; Investigation, Methodology, Software, Resources, Validation, I Nyoman Sudana, Raden Mas Sukarna.

## DECLARATION OF CONFLICT OF INTEREST

We declare that the manuscript titled “Management Model of Rungan Watershed Based on Landscape Ecology at Central Kalimantan” is an original scientific work that has not been published or is under review elsewhere. We confirm that all data, analyses, and interpretations are based on valid research methods and adhere to scientific standards. Proper credit has been given to all quotations, references, and contributions through appropriate citations. This manuscript contains no instances of plagiarism. We are prepared to accept consequences for any future publication ethics violations. All authors have made significant contributions to the research design, data analysis, and writing of the article. No authors are listed without substantial contributions.

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